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A COMPARISON OF LYSIMETER CATCH AND RAIN GAGE CATCH

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A COMPARISON OF LYSIMETER CATCH AND RAIN GAGE CATCH[1/]

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INTRODUCTION

The lack of a reliable standard for checking the amount of precipitation caught by rain gages has been a distinct handicap in precipitation research. Kurtyka (7)[3] cited more than 1,000 articles on precipitation measurement. Many of the authors incorrectly assumed that the rain gage that caught the most precipitation was the best rain gage.

The three weighing lysimeters at the North Appalachian Experimental Watershed near Coshocton, Ohio might provide a nearly perfect standard for checking rain gage performance. The sampling area of the lysimeters is 0.002 acre, about 250 times greater than the orifice area of an 8-inch rain gage. The lysimeters measure the amount of precipitation caught by the ground surface rather than the amount caught by rain gage orifices 3 or 4 feet up in the atmosphere where wind turbulence complicates the measurements. The scales under the lysimeters were tested by the National Bureau of Standards and found to have a sensitivity of 5 pounds, the equivalent of 0.01 inch of water on the surface of the lysimeter (5).

At least three factors, however, detract from the use of lysimeters as perfect precipitation gages. The first is the fact that the grease seals at the lysimeter surface cause unreal weight changes during precipitation (6). The cooling effect of rain on the grease may cause a weight increase in addition to that caused by the weight of the rain. Statistical analyses showed differences between data taken before and after removal of the grease seals.

A second possible source of error is from evapotranspiration; however, this error cannot be large since evapotranspiration conditions are unfavorable during precipitation.

The third and most serious drawback is that of using lysimeters to measure snow. Heavy wet snows that stay in place where they fall present no problem. However, snow drifting onto or blowing off of the lysimeter during precipitation makes it impossible to measure daily or storm precipitation accurately.

EQUIPMENT AND PROCEDURES

The weighing lysimeters used in this study have been described in detail by Harrold and Dreibelbis (6).

Two of the lysimeters, Y102C and Y103A, were cropped in a 4-year rotation of corn (1961, 1965), wheat (1962), and 2 years of meadow (1963, 1964). The other lysimeter, Y101D, was in permanent meadow grass and birdsfoot trefoil until 1964, when it was replaced with an alfalfa-bromegrass mixture. The fields surrounding the lysimeter sites were in the same crop as the lysimeters. No differences due to crop were found in the data.

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[1] Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Ohio Agricultural Research and Development Center.

[2] Statistician.

[3] Underscored numbers in parentheses refer to Literature Cited at the end of the report.

During the 1960-65 study period, construction changes were made on the lysimeter perimeters to eliminate the grease seals which had been causing extraneous diurnal weight gains and losses (6). These construction changes were made in February 1962 on lysimeter Y101D, September 1962 on Y102C, and August 1964 on Y103A. About half of the 1960-65 data were from the period before removal of the grease seals. Technicians from the scale manufacturer checked each scale at least once each year during the study period to insure that they were performing satisfactorily.

Rain gages used in this study were the 8-inch-diameter single-traverse recording type with a 6-inch rain capacity and were equipped with 6-hour charts. The rain gages were checked at least three times per week, and charts were changed after each storm. The rain gages are located within 45 feet of the weighing lysimeters.

Data used in the study were calendar day precipitation totals from the lysimeters and the adjacent rain gages during periods when all three lysimeters were in operation. Measurable precipitation occurred on 637 days during the 1960-65 period, totaling 643.30 inches on the three lysimeters and 571.22 inches on the rain gages.

RESULTS

The effect of removing the grease seals on rain-only catch of the lysimeters was studied by dividing the data into periods when there was or was not a grease seal and then performing regression analyses of lysimeter catch on rain gage catch. The difference between the regressions in the two periods was significant at the 7-percent level. Thus, the grease seal malfunction probably affected rain measurement by the lysimeters.

During periods of snow or mixed snow and rain, the lysimeters caught 47.91 inches of precipitation after removal of the grease seals compared with 37.59 inches caught by the rain gages. The ratio of 1.27 for lysimeter catch to rain gage catch reflected the inaccuracies inherent in the measurement of snowfall. Detailed analyses of the snow were not attempted.

The ratios for rain only of lysimeter catch to rain gage catch after removal of the grease seals are given by months in table 1. For rain only, the three lysimeters caught 239.82 inches compared with 226.49 inches for the rain gages, a ratio of 1.06.

For total precipitation, the lysimeters caught 287.73 inches and the rain gages caught 264.08 inches, for a ratio of 1.09. The average ratios for total precipitation by months are plotted in

TABLE 1.--Ratio of rain-only catch for three weighing lysimeters without grease seals to rain-only catch for adjacent rain gages during 1962-65

Month	Y101D	Y102C	Y103A	Average
January	1.09	1.05	1.12	1.09
February	1.20	1.14	1.03	1.13
March	1.11	1.07	1.15	1.09
April	1.06	1.03	1.03	1.05
May	1.02	.99	1.01	1.01
June	1.02	.98	1.10	1.01
July	1.02	1.02	1.04	1.03
August	1.03	.99	1.02	1.01
September	1.09	1.07	1.04	1.06
October	1.07	1.05	1.04	1.06
November	1.12	1.13	1.16	1.13
December	1.09	1.07	1.07	1.08
Average	1.07	1.04	1.06	1.06

figure 1. The smooth eye-fitted curve is probably a better representation of the seasonal trend than the data points.

Highly significant differences in rain catch were found between the three lysimeter sites. For the period September 1964 through 1965, when all grease seals were removed, the lysimeters at the Y101D, Y102C, and Y103A sites caught 42.47, 41.78, and 42.73 inches of rain, respectively, and the rain gages caught 39.69, 39.06, and 40.26 inches. The ratios of lysimeter catch to rain gage catch were 1.07, 1.07, and 1.06 at the Y101D, Y102C, and Y103A sites, respectively. These agree fairly well with Symon's observations as quoted by Kurtyka (7) which indicated that ground catch would be about 9 percent more than that of a rain gage with its orifice 42 inches above ground level. A summary of the regression results is given in table 2.

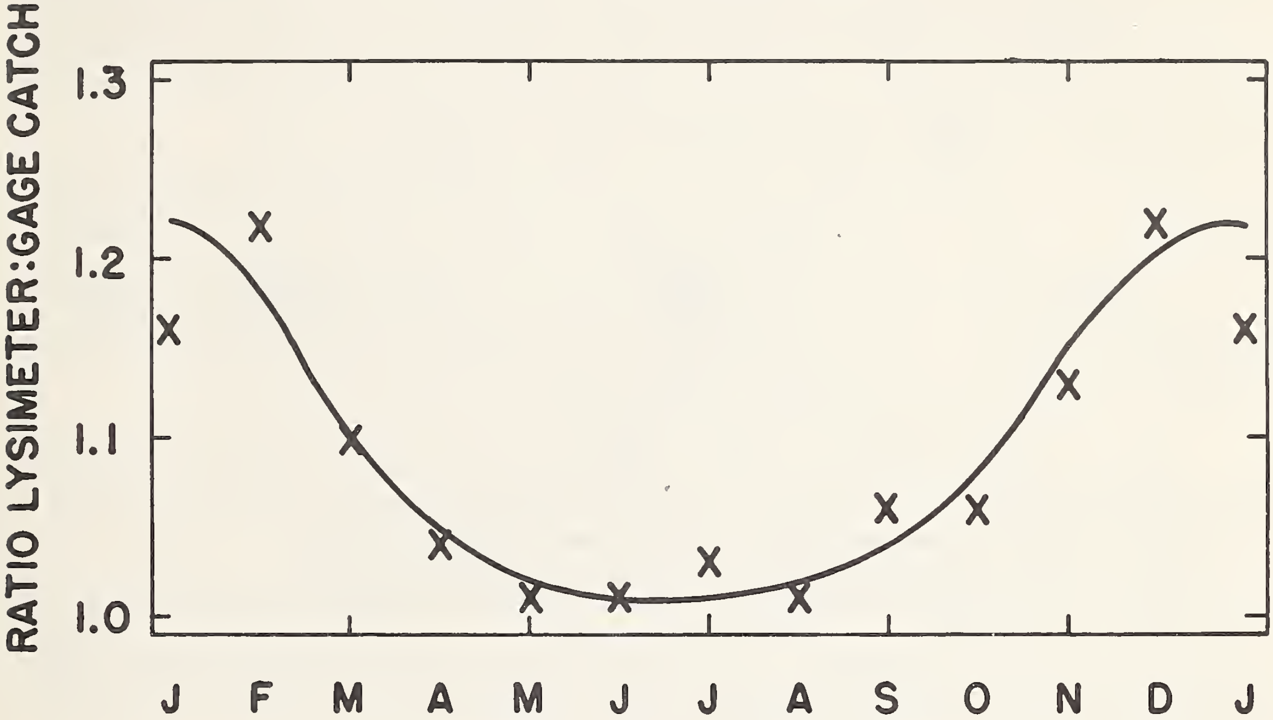

Figure 1.--Ratio of lysimeter catch to rain gage catch for total precipitation after removal of grease seals.

TABLE 2.--Regression equations showing the effect of grease seal removal on the relation between lysimeter catch and rain gage catch, rain only, 1960-65

Lysimeter	Number of days	Regression equations, daily lysimeter catch on daily rain gage catch: Slope	Regression equations, daily lysimeter catch on daily rain gage catch: Intercept	Standard error	Total rain catch: Lysimeter	Total rain catch: Rain gage
				Inches per day	Inches	Inches
With seal:						
Y101D	191	1.03	0.02	0.05	68.31	62.22
Y102C	236	1.01	.03	.05	79.28	72.55
Y103A	385	1.00	.03	.05	133.55	122.89
Without seal:						
Y101D	318	1.03	.01	.04	104.27	97.42
Y102C	273	1.01	.01	.05	92.82	88.84
Y103A	124	1.01	.02	.03	42.73	40.26

During the April to October seasons of 1962 through 1965, a special study of rain measurement was made at the Y101D lysimeter site. Two recording rain gages were equipped with modified Alter shields (10) and two were left unshielded. One rain gage of each pair was installed with the orifice tilted parallel to the 23-percent land slope whereas the second rain gage of each pair was installed with the orifice level. No gage was more than 45 feet from the lysimeter. Analysis of variance of the 4 years of rainfall data (table 3) showed the lysimeter catch to be significantly (4.3 percent) more than the average of the four rain gages, but there were no significant differences between the rain gage catches.

A directional rain gage patterned after the model of Fourcade (3) was operated at the Y101D site. This rain gage had four 8-inch orifices tilted 30° from the horizontal and facing the cardinal directions. The average rainfall was from the southwest (bearing of 234°) at an angle of inclination of 17° from the vertical. Correlation between average windspeed during rainfall and the angle of inclination that the rain made with the vertical was not high (r = 0.53). Windspeed measurements were made at a height of 6 feet. The wide scattering of points precluded any attempt to fit a relationship between windspeed and angle of inclination of rain.

In an effort to clarify some of the relations between windspeed and rain catch, data were analyzed from the 1940-42 period, the only one when complete windspeed measurements were available. The inlet for the anemograph was about 30 feet above ground level and 70 feet from the rain gage. Periods of snow or mixed precipitation were excluded.

The two diagrams on the left side of figure 2 show the directional distribution and average velocity of all winds for the 3-year period. The percentage total in each octant of directional distribution is shown by the radial length of each pie-shaped section. Average velocity from each direction is shown by the length of the heavy lines. There were a total of 67,501 miles of wind in the three growing seasons and 128,835 miles in the dormant seasons.

The middle set of diagrams on figure 2 give the same information as those on the left but only for periods when rain was actually falling. The average wind velocities were noticeably lower during rain periods. The total wind movement during rain periods in the 3 years amounted to 2,683 and 3,199 miles, respectively, for the growing and dormant seasons.

Diagrams on the right side of figure 2 show the 69.90 inches of summer and 34.05 inches of winter rain for the 3 years distributed according to the prevailing wind direction during each rain. The radial length of each directional pie segment is the percentage of total rain. The seasonal contrast is marked. More than 72 per cent of summer rains fell when the wind was blowing from the west, southwest, or south. During the winter season, more than 61 per cent of the rains fell when the wind was from the northeast, east, or southeast.

TABLE 3.--Rainfall totals for four rain gages and weighing lysimeter Y101D during growing seasons, 1962-65

Year	Unshielded gages		Shielded gages		Lysimeter
	Level	Tilted	Level	Tilted	
	Inches	Inches	Inches	Inches	Inches
1962	18.44	18.47	18.47	18.69	19.13
1963	15.05	14.99	15.24	14.65	15.72
1964	18.84	18.77	19.06	18.92	19.47
1965	19.91	19.52	19.66	19.89	20.95
Total	72.24	71.75	72.43	72.15	75.27

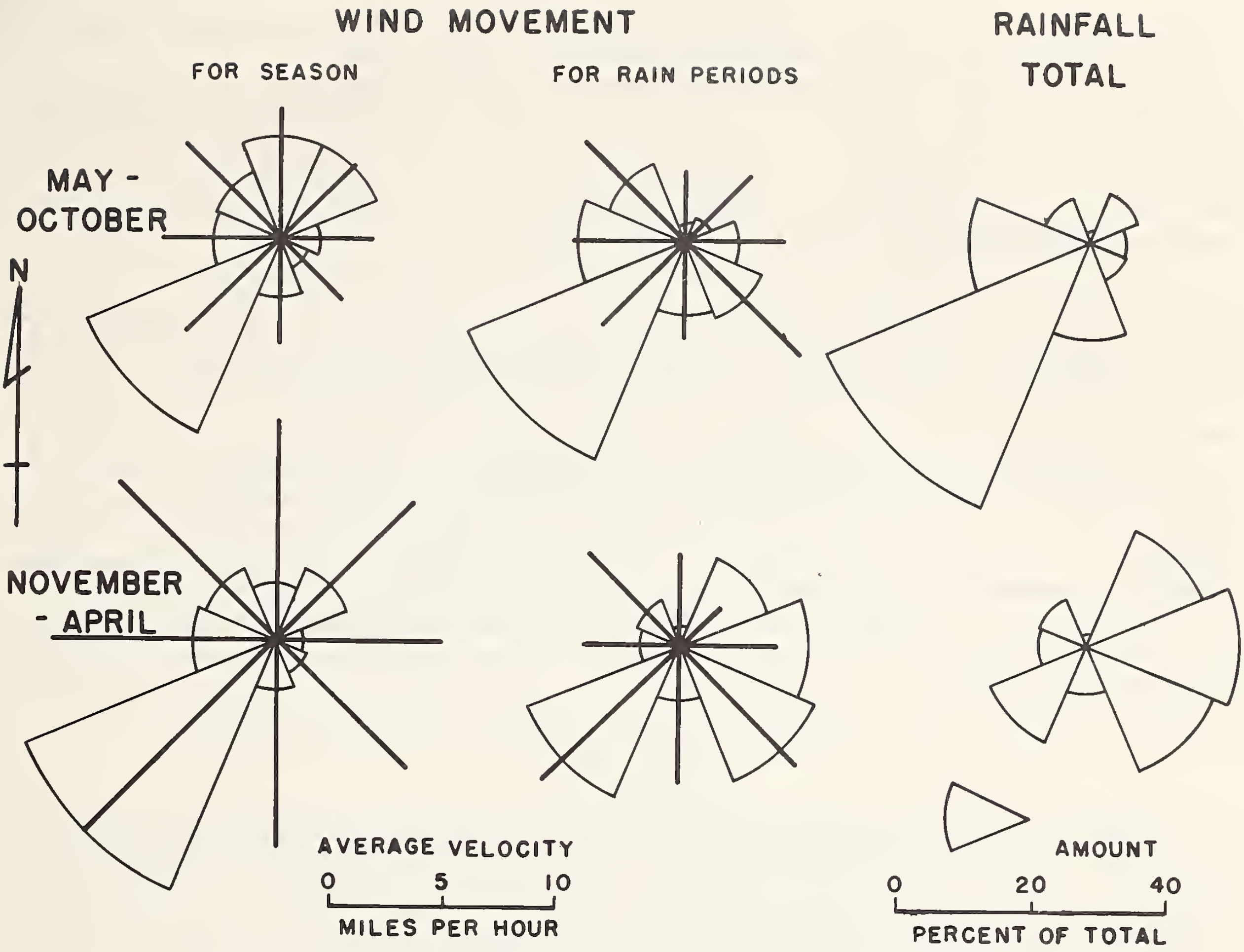

Figure 2.--Windspeed and rainfall relationships, 1940-42, Coshocton, Ohio.

DISCUSSION

Neither the lysimeter nor the rain gages were adequate for measuring snow. Observations of snow blowing onto and from the lysimeters precludes their use as a standard during snow periods, and the rain gage is notoriously unreliable for measuring snow.

The data of table 2 indicate that the lysimeters may not have been a good standard of measurement when they were equipped with grease seals. During rainfall, the grease cooled and caused an unreal weight increase. Removal of the seals brought the ratio of lysimeter catch to rain gage catch closer to 1:1 and reduced the standard error of the regression estimates (table 2).

The effect of windspeed on lysimeter catch and rain gage catch is not clear. The average ratios in the last column of table 1 show a striking seasonal effect. From May through August, the ratio of lysimeter catch to rain gage catch was low, averaging 1.01. In March to April and September to October, it was 1.07, whereas from November through February, it was 1.11. The average wind velocities at the Akron-Canton Airport were 8.2, 10.2, and 11.6 miles per hour, respectively, for these same monthly periods. Although these wind data are in the same order as the average ratios of rain catch, not too much faith should be placed in this type of relationship, as evidenced by the data of figure 2.

According to one scheme the Y101D, Y102C, and Y103A sites are classified as protected, fairly well protected, and moderately windy (1). Then the adherence to a 1:1 relationship of lysimeter catch to rain gage catch should rank greatest to least in this same order, but the actual order is Y102C, Y103A, and Y101D. Recent data from Michigan (2), however, suggest that even very subtle topographic variations may influence rain gage catch.

Using the modified Alter shields and tilting the gage orifice parallel to the 23 percent land slope did not influence the amount of rain gage catch (table 2). Shielding rain gages has been reported to be most effective in increasing snow catch (11) but much less so for rain. There was no evidence of wind effect on rain gage catch (table 2), yet the lysimeter caught 4.3 percent more rain than the average of the rain gages (table 3). Is there still a wind effect on rain gage catch which has not been removed?

The lysimeter Y101D site where the data of table 2 were obtained is on the lee of a hill that protects it from the prevailing storm direction. Data from experimental forests in Eastern United States (9) suggest that rain gages on the lee of sheltering slopes will not show the differences due to tilting that were found in California (4). The average angle of inclination of rain at Coshocton, 17°, was much closer to the 18° to 19° measured during the growing season in southern England (8) than to the roughly 26° found in southern California (4).

Wind movement during rain periods was not distributed the same as total wind movement (fig. 2). Thus the use of such factors as monthly wind totals or average monthly velocities in correlation with rain gage catch does not appear to be warranted here. The difference in wind velocities and directional wind distribution for rain periods and total wind movement were especially pronounced in the dormant season. In the growing season, most of the rain is from the southwest and the greatest wind movement and highest velocities are from this direction. In the dormant season, most of the rain is from the east, but the seasonal prevailing wind is still from the southwest.

SUMMARY

A comparison was made between the precipitation catch of three weighing lysimeters and that of their adjacent recording rain gages. Factors considered in making the comparison were the influence of grease seals on lysimeter catch, and the effects of windspeed, shielding, degree of slope, evapotranspiration, and blowing snow.

The ratio of lysimeter catch to rain gage catch after removal of the lysimeter grease seals was 1.09 for total precipitation. For rain only the ratio was 1.06, but for snow and mixed precipitation the ratio was 1.27. Changes in the perimeters of the lysimeters had different effects on the amount of catch at each of the three lysimeter sites. Windspeed, shielding, and degree of slope were of no use in explaining the differences between lysimeter catch and rain gage catch.

Removing the lysimeter grease seals has probably made the lysimeters a better standard for checking the performance of rain gages. However, the differences between lysimeter catch and rain gage catch ratios at the three sites and the inability to show the effect of windspeed on catch indicate that much remains to be done.

ACKNOWLEDGMENT

I am endebted to C. A. Salrin for assistance with the analyses.

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